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WEAR RESISTANCE OF GLASS ENAMEL COATINGS FIRED IN A HIGH-FREQUENCY ALTERNATING FIELD

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The effect of firing glass-enamel coatings in a high-frequency alternating electric field on their wear resistance is studied. It is shown that wear resistance grows 2.8 – 5.5 times depending on the type of the coating. Ellipsometric studies established that the increase in wear resistance of glass-enamel coatings formed under the effect of a HF field is inversely proportional to the variation of the refractive index of the glass matrix.

Since enameled chemical equipment has to withstand abrasive wear, the wear resistance of glass enamel coating has to be increased [1, 2]. The mechanical parameters of coatings are usually improved using three methods [2, 3]:

– partial devitrification of glass enamel coating;

– creation of glass enamel composites by introducing microcrystals of zirconium, aluminum, and other oxides;

– construction of multilayer coatings with combinations of various types of glazes (devitrified, glass ceramic, vitreous).

The specified methods make it possible to increase the abrasive wear resistance by 20 – 100%, sometimes lowering chemical resistance. It is demonstrated in [2] that the rate of corrosion-abrasive wear is not a function of the rate of corrosion and the rate of abrasive wear. Consequently, the abrasive wear resistance of the coating should be increased with a simultaneous increase in corrosion resistance, which is possible by developing a matrix with a preset structure in the glass-enamel coating.

It is possible to increase the corrosion resistance of a coating and improve its mechanical properties under firing with the imposition of a high-frequency (HF) alternating electric field [4, 5]. We investigated the same enamels as in [1]: enamel UÉS-300, glass-ceramic enamel 631, enamels K-17 and 5Ts with a heterogeneous microstructure, and enamel No. 261, which is an amorphous material with a microheterogeneous chemical composition [2].

To verify the effect of the HF field on the structure of enamel frit, its effect on the glass structure was investigated in vitrification of a melt in the system $SiO_2 – ZrO_2 – B_2O_3 – RO – R_2O$, which is the basis for enamel UÉS-300 [6, 7]. The glass samples brought to melting at a temperature of 977°C were cooled under a HF field produced by a VChD-2.5/40 generator to room temperature. The electric field frequency was 40.68 MHz and its power 2 kW.

After vitrification, anisotropic growth of microhardness of glass was registered: from 4.5 GPa in initial glass to 6.5 – 9.0 GPa after vitrification in a HF field. The methods of cathode luminescence and annihilation of positrons revealed the anisotropy of glass structure in the plane parallel to the condenser lines of force [5]. Thus, the degree of covalence of the cation – oxygen bond anisotropically increases directly with microhardness. The electron microscope data indicate that laminar formations up to 350 nm thick emerge along the field lines of force (Fig. 1).

Samples sized 50 × 50 × 3 mm made of steel 08kp with enamel slip deposited were fired in the furnace between the condenser plates. As the HF field produces additional heat-

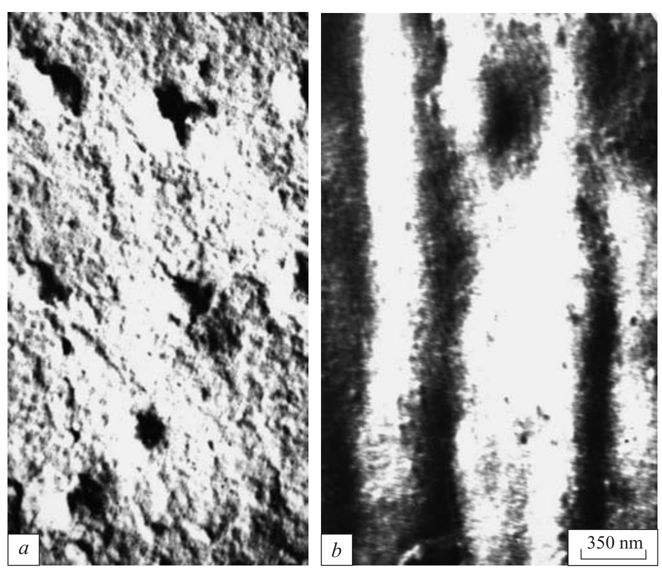

Fig. 1. Electron microscope photos of glass enamel UÉS-300 after firing in HF field in the plane perpendicular (*a*) and parallel (*b*) to the field lines of force.

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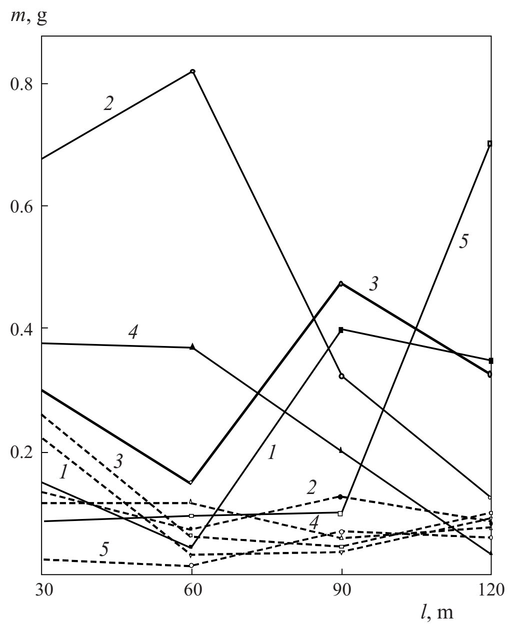

Fig. 2. Weight loss *m* in glass-enamel coatings No. 261 (*1*), No. 631 (*2*), K-17 (*3*), 5Ts (*4*), and UÉS-300 (*5*) depending of the path length *l* of abrasive wheel: continuous curves) initial enamels, dashed curves) after firing in HF field.

TABLE 1

Enamel	Heating temperature, °C		Anode current, A	Anode voltage, kV	Firing duration, min
	in furnace	in HF field			
No. 261	780	800	0.38	3.1	25
UÉS-300	780	800	0.40	3.2	30
No. 631	790	860	0.36	3.0	25
5Ts	820	870	0.36	2.7	25
K-17	830	870	0.26	1.8	25

TABLE 2

Enamel	Structural type of enamel	Wear resistance increase, times	Refractive coefficient	Linear thickness of layer, nm
No. 261	Vitreous	2.8	2.11/2.11*	94.3/91.5*
5Ts	With heterogeneous microstructure	3.0	2.20/2.00	88.7/102.2
K-17	The same	3.2	2.14/2.10	89.5/103.1
No. 631	Devitrified	5.5	2.10/2.05	90.1/104.3
UÉS-300	Glass ceramic	3.7	1.72/1.84	118.6/108.6

* Front of slash) initial glass ceramic coating; back of slash) coating fired in HF field.

ing of enamel, the furnace heating temperature was selected lower by 50 – 40°C than the standard temperature accepted for the particular enamel. After reaching the selected temperature, the electric field produced by a LD1-4 generator was turned on. The exposure lasted 10 – 15 min (the maximum temperature is indicated in Table 1). After the exposure the furnace was turned off, then the sample was cooled for 10 – 20 min under the effect of the HF field to 450°C, and the field was turned off (Table 1).

The wear resistance of glass-enamel coatings was determined using the method described in [1]. It can be seen from Fig. 2 that the wear of enamel after 30 m-path of the abrasive wheel proceeds more uniformly after firing in the HF field than in the initial coatings. The wear resistance of enamels treated on the HF field has grown 2.8 – 5.5 times.

To identify the reasons for increased wear resistance of coatings, the ellipsometry method was used (Table 2). It was found that the wear resistance of enamels 5Ts and K-17 grows approximately equally; at the same time, the thickness of the homogeneous glass layer increases in both coatings, which may be attributed to the increased degree of polymerization of the glass phase. This applies as well to devitrified enamel No. 631 that has the maximum wear resistance increment. The increase in the refractive index in enamel UÉS-300 may be caused by the process of microliquation of the complex polyanion under the effect of the HF field.

Thus, the increased wear resistance of glass-enamel coating under the effect of the HF field is inversely proportional to the variation in the refractive index of the glass matrix.

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